Landscape Leafy Spurge Susceptibility Mapping using Landsat Satellite Imagery and Local Weed Distribution Data

Final Report

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Background

In Idaho, leafy spurge (*Euphorbia esula*) has been reported in 40 of 44 Idaho counties and originally discovered around 1910. Bingham County contains 52 leafy spurge sites. In 2009, South Eastern Idaho Counties reported the locations of 2584 leafy spurge infestations ranging in size from a few plants to over 100 acres. The total area of Bingham County is 2120 square miles of which 2,095 square miles is land and presents a challenge for limited county resources to survey land susceptible to leafy spurge invasion.

The idea for predicting susceptibility of the landscape to leafy spurge was first explored by Hamilton, Lachowski and Campbell in 2006 and later refined by E. Raymond Hunt, Jr. Their work used a Weed Invasion Susceptibility Prediction (WISP) developed by Gillham et al in 2004. The WISP Model stacks environmental and feature data in layers to determine if a site can support leafy spurge. It is a binary approach where each layer is defined as 1 supports leafy spurge or 0 does not support. The model simply adds the number of layers favoring leafy spurge establishment to determine the score for susceptibility. Suggested layers for determining leafy spurge occurrence on the site are roads, type of lane use, soil type, streams, aspect, precipitation and elevation and based on training data having leafy spurge infestations. Their results in both Utah and Wyoming suggest stream beds near roads and south eastern aspects score 8 or more on the WISP scale. Unfortunately that covers a lot of area in a county. In the case of Crook County, Wyoming, WISP may indicate 35% of the county has a score of 9 and 60% has a score of 8 or higher.

An alternative approach to site susceptibility modeling is grounded in ecological theory where plant occurrence is related to plant community productivity and climate factors. We started to promote the use of likelihood of occurrence models in 1994 for plant survey and in 2000 to improve remote sensing image classification. The models have matured into an understanding that a species ability to invade a site has ecological limits defined by competitive limits and ability to survive stresses imposed by climate. The model still stacks and adds in the form of a logistic regress equation where each feature is defined by a gradient rather than the binary 0 or 1. The advantage of logistic regression is greater precision when identifying susceptible sites over a large landscape.

The purpose of this project was to assist Paul Muirbrook, Bingham County Noxious Weeds, in identifying high priority areas for survey and treatment in the Blackfoot River Watershed during the 2009 field season.

Project Objectives:

Acquire best available leafy spurge (*Euphorbia esula*) distribution data (including entire area surveyed in addition to weed locations)

Generate a leafy spurge landscape susceptibility map for the area encompassed by the most recent Landsat Scene encompassing eastern Bingham County, Idaho

Join remotely sensed data with leafy spurge distribution maps to create susceptibility map products which will:
- identify high priority areas for leafy spurge surveys
- identify high priority areas for leafy spurge treatment (herbicide, biological control, grazing, etc.)
- enable weed professionals to communicate with the public and decision makers about the current status and future threat of leafy spurge in the Blackfoot River Watershed.

Methods:

The limited number of infested sites in Bingham County prevented the use of WISP models to predict the susceptibility of the site to invasion. We chose to use a regional approach to develop a leafy spurge occurrence model using location data from all of South East Idaho and apply the model to Bingham County.

Leafy spurge distribution map data were obtained from Paul Muirbrook and staff of Bingham County. Data for surrounding counties was obtained from Stephen Cox of Idaho Department of Agriculture. Additional leafy spurge location data were obtained from the BLM. Validation of the survey data were not conducted for this effort and authors of these data indicated leafy spurge presence data were collected with a GPS with 3 to 5 m accuracy. Data showing areas without leafy spurge were not available. Mapping standards loosely followed North American Weed Management Associations Mapping Standards (http://www.nawma.org/, last modified 1/29/2003). The survey observations were used to construct a presence/absence map of leafy spurge infestations for southeast Idaho (everything East of Burley, Idaho) at a resolution of 10 m by 10 m.

Point and line data were spatially defined using information from the associated data table. Line data was buffered 25 m when not spatially specified in the associated data table. A distance of 25 m was an estimated viewing width given the surveyor's field of view. Points noting the center of the infestation were converted to spatial data using a 25m buffer for 0.1 acre, 50 m buffer for 0.5 to 0.75 acre 100 m for 1 acre and 150 m for 1.1 to 10 acres infestations. Point data representing infestations larger than 10 acres were not used for data analysis. Polygon data were spatially buffered 10 m to allow for a slight increase in infestation size since survey date and insure all plants were included in the analysis. All the buffered data were merged into a single file and grouped so overlapping pixels would be counted as a single infestation.

The grouped data were randomly split into model development data representing 60% of the infestations and model validation data representing 40% of the known infestation in southeast Idaho.

Model Components

Independent variables tested in development of the occurrence model included slope, aspect, elevation, sunlight difference, heat units, and vegetation indexes (STVI and TSAV). There is some dependence among these variables. For example, southwest facing steep slopes receive full sunlight, tend to dry faster, and have less vegetation than north facing slopes or even slightly

sloped land with a southwest facing aspect. The same can be shown where a lower elevation with slopes receiving sunlight will have higher accumulated heat units than north facing slopes at higher elevations, or even the same amount of sun at higher elevations on the mountain.

The slope, aspect and elevation data were from USGS National Elevation Dataset (1/3 arc second) with a spatial resolution of 10 m.   Repetitive striping was visible in the slope and aspect data generated from the National Elevation Data Set and was found to be a result of stripes of the same elevation in the data. The elevation data were digitally filtered using the median of 5x5matrix of neighboring pixels to remove the stripes. Slope data were grouped into 5° intervals and aspect was grouped into 22.5° intervals to reduce any smoothing effects of the filtering process.   Aspect data were weighted and categorized (1 to 8) to reflect the sun's effect from solar radiation so highest values of the aspect class were at 237°and lowest values were at 45°.

  Sun angle difference data subtracted June's estimate of the amount of the hill shaded based on slope and aspect and the sun angle for June 12 (63°) at sun azimuth of 213° from March's hill shade using a sun angle from March 12 (36°) and 213°sun azimuth. The 213° sun azimuth represented the beginning of the warmest part of the afternoon (13:45). The sun angle difference data show areas always receiving full sunlight and partial shaded areas when plants are developing.

Accumulated growing-degree-day data were derived from PNWPest.org using 30 year average temperature and 6° C lower temperature threshold from March 12 to June 12 with county and state lines removed. The image generated by the website was a 24-bit color composite. The image was converted to an 8-bit image by separation of the 24-bit image into RGB components. The RGB bands were grouped with histogram-peak cluster analysis using unsupervised classification.   Each cluster was assigned an accumulated growing-degree-day value based on location on the original 24-bit image and a map legend file provided by the PNWPest.org site showing the color and accumulated growing-degree-day values. The clustered accumulated growing-degree-day image was transformed to 10 m spatial resolution with linear regression using elevation and sun angle difference image as independent variables.

Stress Vegetation Index (STVI) and Transformed Soil Adjusted Vegetation Index (TSAVI) were calculated from red and near infrared bands of LandSAT 5 data acquired April 13, 2007 and July 18, 2007. Images were georeferenced using National Agricultural Imaging Program (NAIP) images for reference and the spatial resolution reduced to 10m by 10m using nearest neighbor analysis prior to calculating the vegetation indexes.

$STVI = ([MIR*R]/NIR)$

$TSAVI = ([a]*(([NIR]-[a])*([Red]-[b])))/(([Red]+[a])*([NIR]-([a]*[b]))$

        where [NIR] = Near-infrared band
                [Red] = Visible red band
                [a] = Slope of the soil reflectance model
                [b] = Intercept of the soil reflectance model

The STVI and TSAVI values were scaled to match training sites. STVI estimates the percent water stressed vegetation cover or low mid-season competitive vegetation while the TSAVI indicates the amount of living vegetation present (biomass) adjusted for soil background. Hence, both indices provide information on competitive ability. The STVI and TSAVI image was squared to provide an additional term in the model.

Susceptibility Model

The independent variables used in the development of productivity models should reflect conditions and factors that influence leafy spurge development and potential to reproduce. Information on the environmental and climatic factors were not available for each infested site and were prohibitive to obtain in the grant duration without coarse interpretation over large area between observation stations. An alternative method was used where topographic factors, such as elevation, slope and aspect and environmental conditions such as sunlight and heat units, as-well-as competitive correlates such as vegetation indexes related to plant community biomass were used to model site susceptibility or likelihood of leafy spurge occurrence.

The model used was binomial logistic regression to calculate a predictive image showing susceptible sites. A stratified sampling scheme of leafy spurge training data was used to reduce spatial interdependence where weed free and weedy areas may have had a few misclassified pixels. An area of interest mask of 500 m around all leafy spurge locations was applied to increase the likelihood the weed free and weedy areas had been surveyed.

Tests of each independent variable were developed as well as combinations of the variables. The relative operating characteristic (ROC) statistic was used to determine model fit. A perfect fit has a value of 1 and a random fit will have a value of 0.5.

Results and Discussion.

Meeting Objective 1. Acquire best available leafy spurge (*Euphorbia esula*) distribution data (including entire area surveyed in addition to weed locations).

A presence/absence map of leafy spurge infestation for southeast Idaho was constructed and converted to raster data with a 10 by 10 m grid.

High resolution image data has revolutionized our ability to visualize locations and weed patches. Current North American Weed Management Associations Mapping Standards adopted in 2003 result in coarse resolution survey data and dilute the ability to use the information for further data analysis with high resolution image data. The continued use of non-spatial data such

as points and lines leaves important information about the infestations extent and shape of the out of the modeling process and restricts their usefulness.

Realizing there is a cost/return to data collection, our efforts are enhanced when polygon data collections for all infestations over 0.1 acres. A patch size of 0.1 acre is visually the size of large modern house footprint. New GPS devices taking advantage of WAAS and GMS technology together with NAIP background maps allow users to either walk the weed perimeter or define it with the pen stylist. Accurate infestation borders reduce errors in modeling because there are numerous instances when a leafy spurge infestation abuts areas not susceptible to invasion and when infestation borders mistakenly include insusceptible habitat, our models become less predictive.
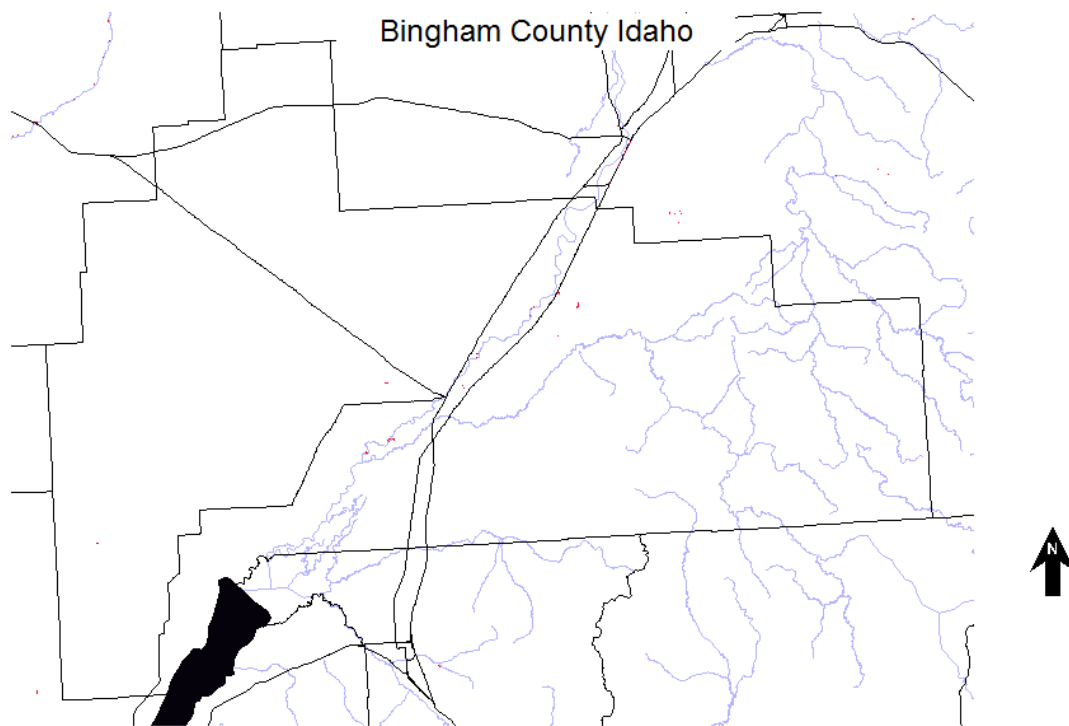

Figure 1 Leafy Spurge infestations in Red.

Meeting Objective 2. Generate a leafy spurge landscape susceptibility map for the area encompassed by the most recent Landsat Scene encompassing eastern Bingham County, Idaho.

The small sample size of Bingham County required expanding the area of interest to South Eastern Idaho when developing and testing the susceptibility model. The advantages of including a larger area are compounding since the susceptibility model estimates the likelihood of occurrence for an increased number of habitats and locations.

Several model scenarios were run but the best fit proved to be the Sun angle difference + STVI + elevation model. Model results showed the predicted likelihood of occurrence for south eastern Idaho ranges from 0.0026 to 0.0032 for known leafy spurge locations. This is a fairly low likelihood of occurrence and equal to about 26 to 33 in 10,000 ratio. Since leafy spurge has not

moved to all potentially infested sites, the probabilities remain low and should be interpreted relative to the maximum and minimum probabilities.

Hardening the likelihood of occurrence data into 6 groups establishes a susceptibility map where group 0 indicates areas where leafy spurge is not known to occur and where group 5 indicates areas where leafy spurge is likely to grow (Table 1 and Figure 2)).

Table 1. Susceptibility Model Validation Table

Grp.	% Infestation in training data	% infestation in validation data	Map color
0	0.0	0.0	White
1	2.6	3.6	Dark green
2	20.1	38.8	Light green
3	42.8	33.6	Yellow
4	23.1	16.4	Yellow
5	11.4	7.5	Red

Areas in group 0 have no leafy spurge based on both the training data and validation data, therefore survey time should be minimized. Group 1 has less than 4% of the leafy spurge found in south eastern Idaho and may be productive when surveying in a rapid response mode when spurge is new to a county. Both training and validation sites appear to have greater numbers of infestations in the lower groups, suggesting either that Bingham County differs in the conditions that promote leafy spurge or that the initial location of infestations in Bingham County is determined by where human introduction occurs rather than where leafy spurge is better adapted.

For Bingham County, the model suggest 16% of the county has sites that are not very susceptible to leafy spurge invasion (Groups 0 and 1 in Table 2).   The model found 34% of the county was highly susceptible to invasion (Groups 4 and 5). Unfortunately, much of the current infestations are found at sites with lower predicted levels of occurrence (Groups 2 and 3). Combining Groups 2 and 3 to the areas that should be surveyed encompasses almost 85% of the county and prevents using the model to direct survey efforts.
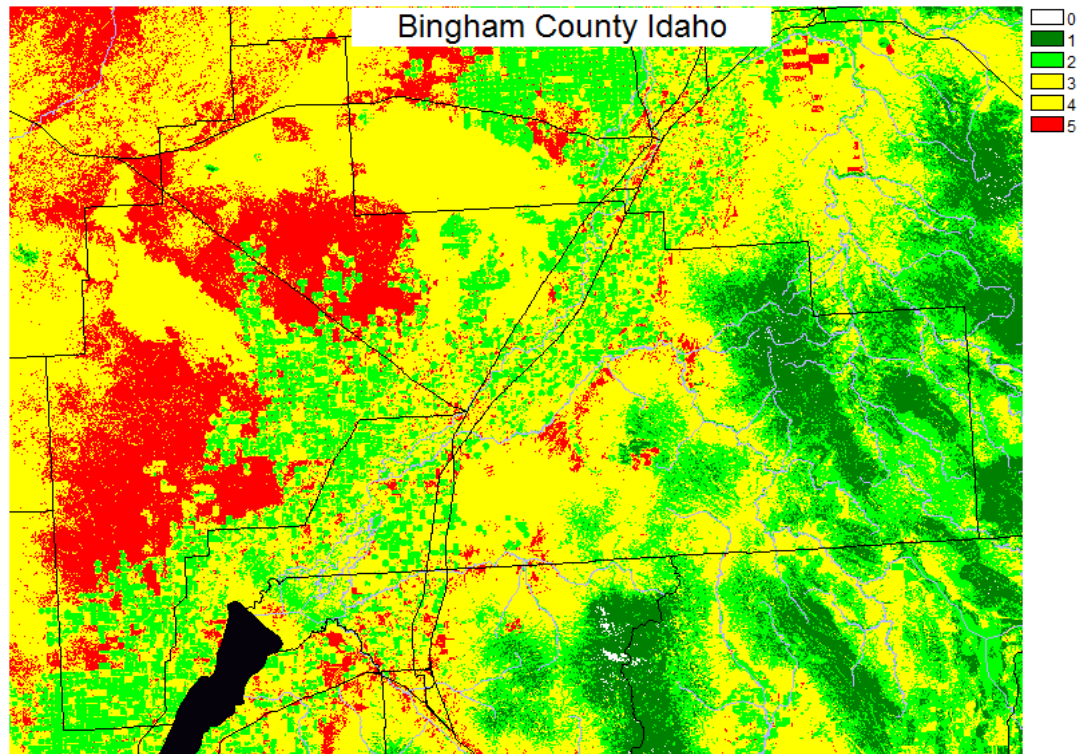
Figure 2 Leafy Spurge Susceptibility Map (ranked 0 = lowest to 5=highest)

Table 2. Percent of Bingham County susceptible to leafy spurge based on the model.

GRP	% Bingham County Area
0	1.1
1	14.6
2	22.4
3	28.5
4	16.2
5	17.4

Seed transport along roads and streams impacts the location of leafy spurge. In the case of roads 52% of the known leafy spurge populations of southeastern Idaho are within 500 m (1600 ft) of a highway or 100 m (320 ft) of a road (streets or local and farm roads) right-of-way. For streams and rivers 30% of the infestations known in south eastern Idaho are within 200 m (640 ft) of water. If we expand the buffer around the water feature to 500 m (1600 ft) then 43% of the infestation is found. Combining both roads and water with 200 m (640 ft) buffer yields 69% of the known leafy spurge infestations and 75% when combined feature includes a 500 m (1600 ft) water feature buffer. The high occurrence within a few meters of transportation routes and water may have contributed to the success of WISP leafy spurge models when predicting the early-invasion sites in Wyoming and Utah. The transportation routes and water corridors filter reduces the survey area to 30% of Bingham County (Fig. 3).
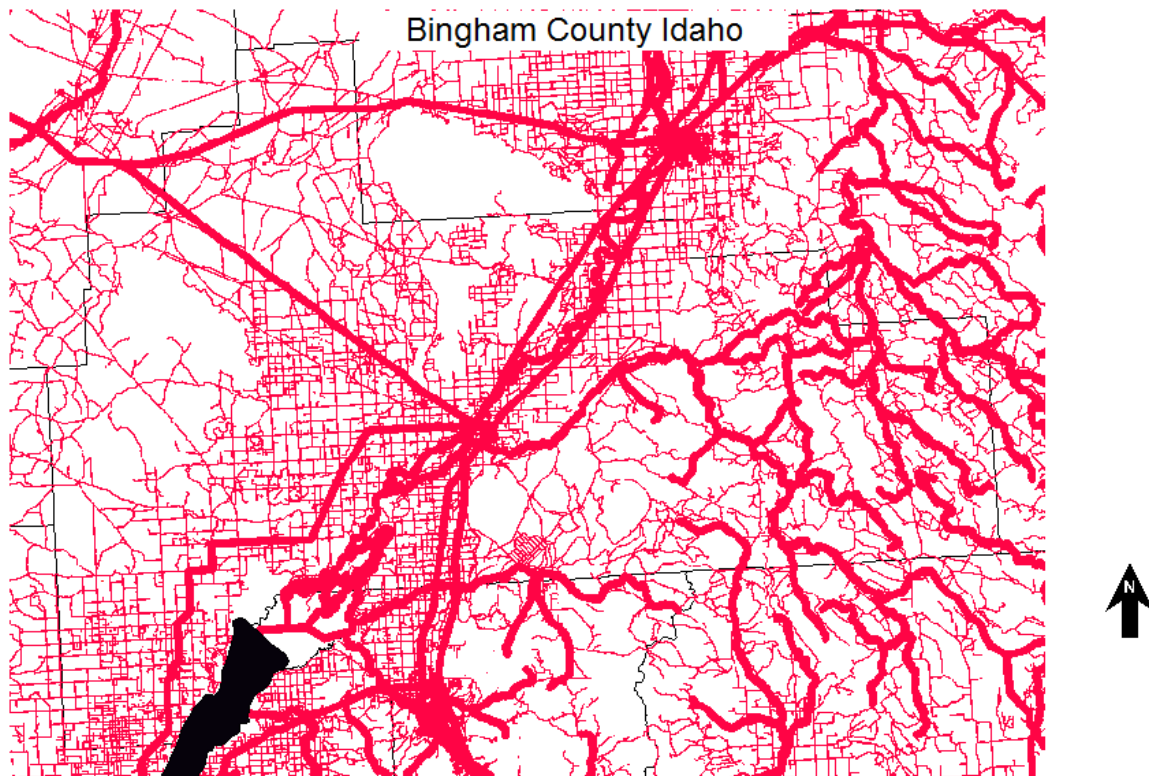
Figure 3Buffered Transportation and Water Features.

Filtering the susceptibility model with seed dispersal mechanisms does indicate slight reductions in the amount of leafy spurge falling into groups 1 and 4 and reflected increases in groups 2 and 3 (Table 3). This suggest a logistic regression for transportation routes may improve accuracy, but when tested proved to only slightly improve the results and does not warrant having two models (data not shown).

Table 3. Susceptibility Model Validation Table with transportation routes filter.

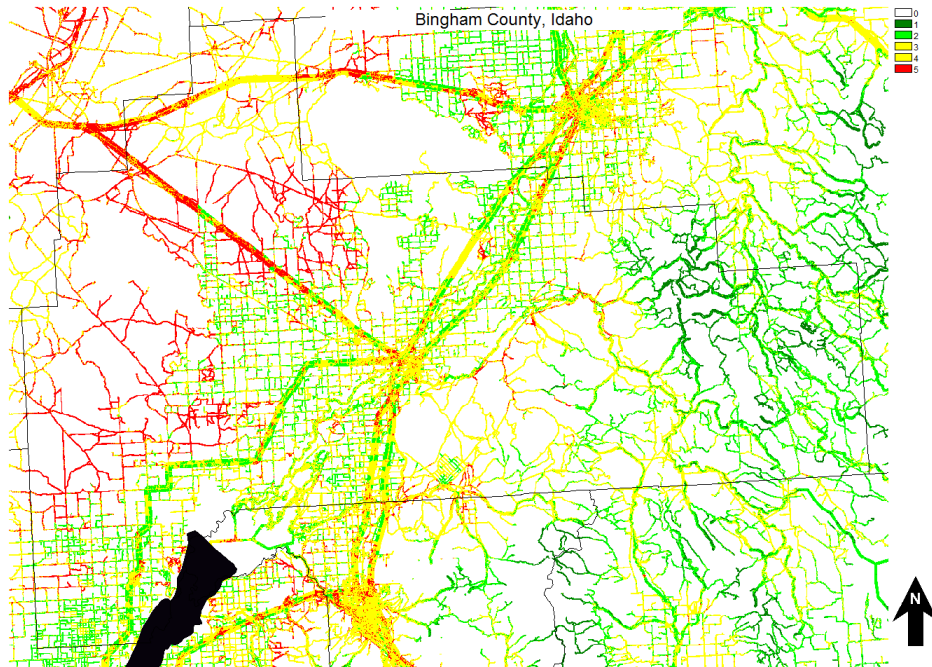| Group.	% Bingham County Area Prior Classification	% Infestation in training data	% infestation in validation data
0	1.1	0.0	0.0
1	14.6	1.9	3.2
2	22.4	21.0	44.6
3	28.5	44.5	33.5
4	16.2	21.4	14.8
5	17.4	11.1	17.9

Figure 4 Intersect of occurrence model with dispersal (roads and water).

Red (5) represents high survey priorty areas, yellow moderate (groups 3 and 4 and green low priorty area.

Past experience shows the best site for leafy spurge growth may not be the site receiving seed. Adding a 200 m buffer around Group 5 found 46% of the leafy spurge in South East Idaho. Most populations in southeastern Idaho were found with the 200m buffer of Group 5 (Figure 5). Error assessment was maded with South East Idaho validation data.   High errors of omission occurred only in Butte County where leafy spurge infestations were along canals and waste water ditches. This would suggest Group 5 with a 200m buffer also could be used as another method to delimit the survey area with the understanding canals and waste ditches would need to be included in the survey area. In the case of Bingham County results of the 200 m buffer of Group 5 still produces a large area to survey (Figure 5).
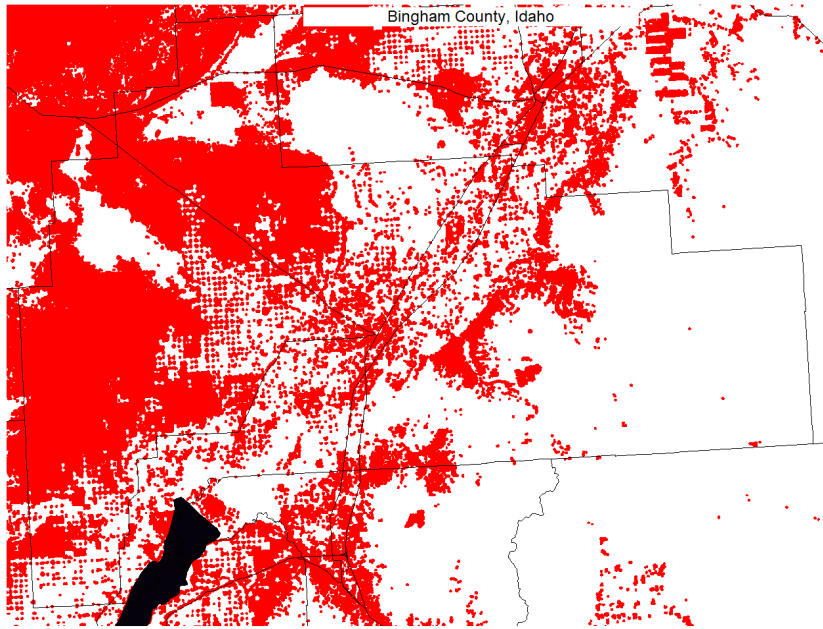
Figure 5 Group 5 with 200m buffer.

<u>Meeting Objective 3. Join remotely sensed data with leafy spurge distribution maps to create susceptibility map products which will:</u>

- <u>identify high priority areas for leafy spurge surveys</u>
- <u>enable weed professionals to communicate with the public and decision makers about the current status and future threat of leafy spurge in the Blackfoot River Watershed.</u>

The predicted occurrence model suggests the likelihood of finding leafy spurge is 2 to 3 in every 1000 sites visited. The current susceptibility map indicates 84% of Bingham County may ultimately have some leafy spurge. We were able to show 75% of the leafy spurge infestations in southeastern Idaho are currently found either near water or transportation routes. Over 50% of known infestations in southeastern Idaho are within 500 m (1600 ft) of a highway or 100 m (320 ft) of a road (streets, local and farm roads). Human activities where seed or roots are transported becomes important for determining where to survey.

The small number and size of known leafy spurge infestations in Bingham County changes priorities in survey because seed sources will come from human activities rather than natural occurrences. The first survey priority should expand the search areas aroundbe recreation areas currently infested with leafy spurge by 500 m to find all plants. This would potentiallyto reducee long distance transport to new sites in the County (Figure 6). Second survey priority should be infested agricultural land and canals and waste water ditches near currently with an infestations and using a search area based on Figure 4. Special focus should be place on equipment transport when the seed is ripe such as hay or harvest equipment movement and where contaminated product may have been transported. Third survey priority is to track log Road Maintenance and

Construction Equipment when in areas known to have leafy spurge infestations and movement into susceptible sites (Figure 1 and 4). For example in Madison County, Montana, if the contractor built a home near land infested with leafy spurge the next home they built also had leafy spurge. It is also true with road maintenance equipment. In the case of roads, experience in Madison county suggests know infestations should be intensively surveyed for 500 m (1600 ft) on either side of the infestation and this could be up to 1 km (0.6 mile) from the last known plant to insure the extent of the infestation is found.
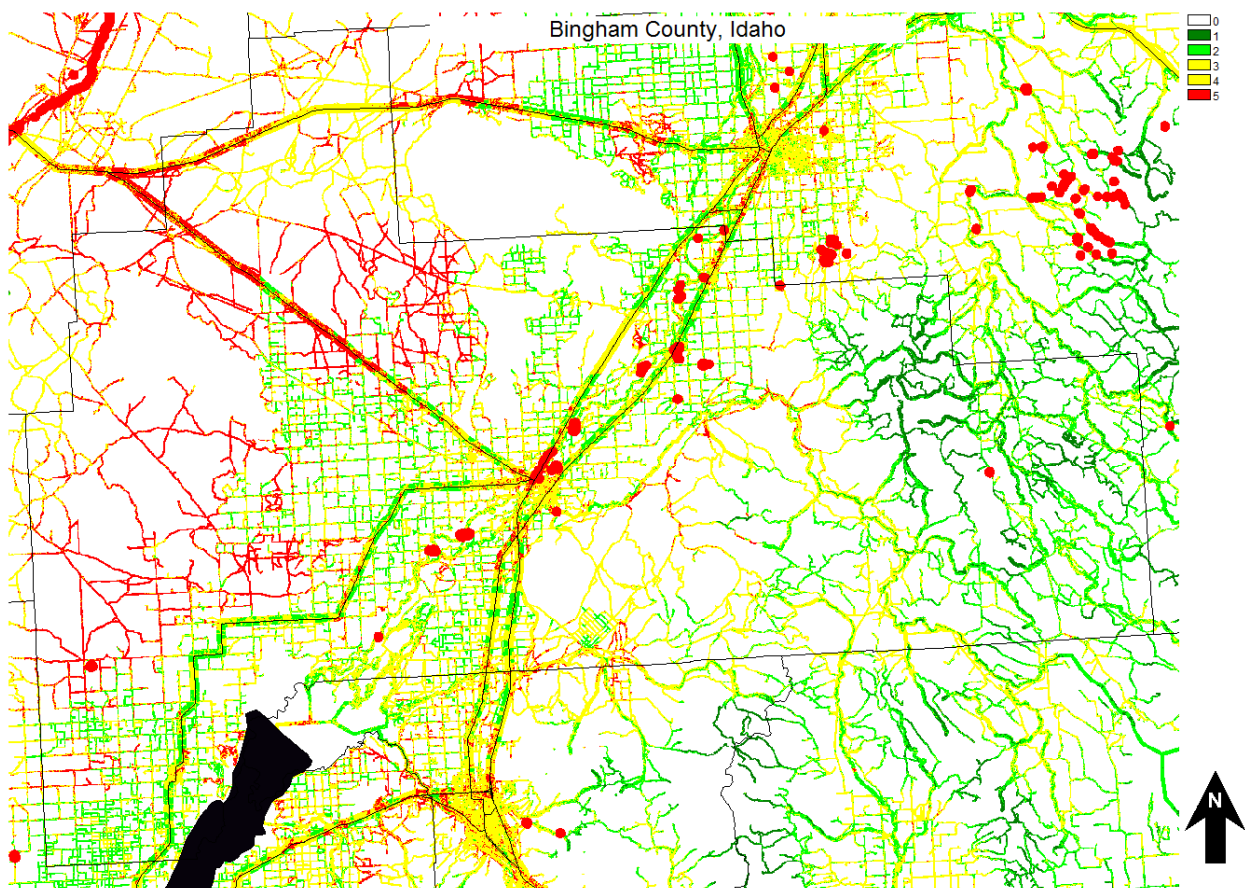
Figure 6 Survey priorities (red highest to green lowest).

- identify high priority areas for leafy spurge treatment (herbicide, biological control, grazing, etc.)

There are 6 groups of susceptibility from 0 to 5. In theory if Group 0 has no leafy spurge and Group 5 (Fig. 6) has the highest likelihood of occurrence then intermediate groups should have less desirable growing conditions as the group number decreases. If the plants growing in Groups 1 and 2 are assumed to be under stress, spurge plants may be susceptible to changing competitive advantages with timed grazing or biological control.
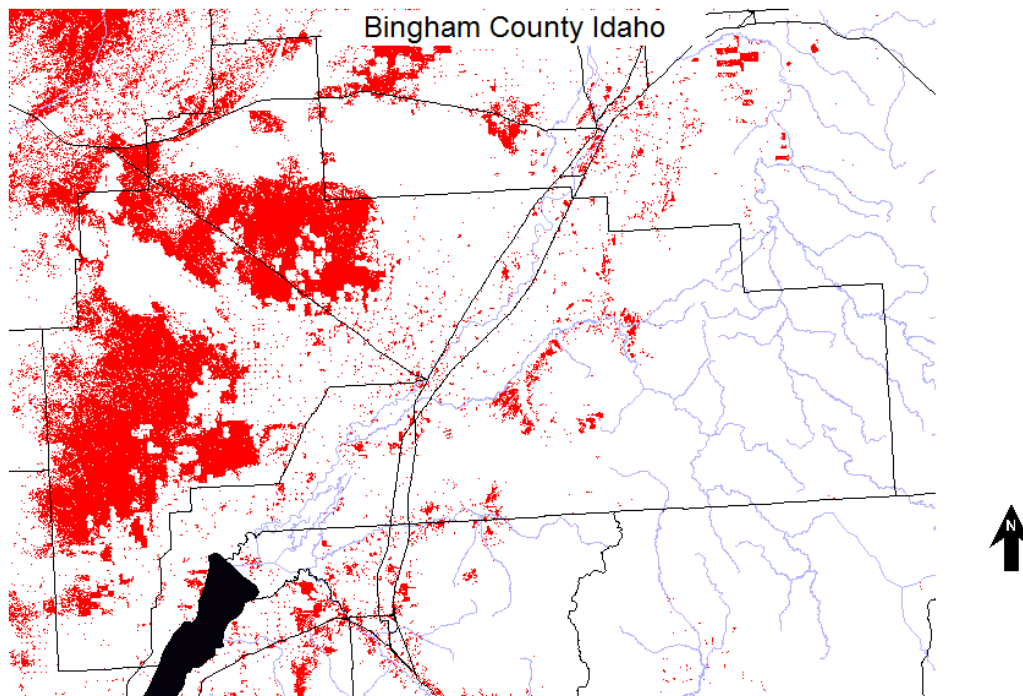
Figure 6Highest Susceptibility Group 5 in Red

- enable weed professionals to communicate with the public and decision makers about the current status and future threat of leafy spurge in the Blackfoot River Watershed.

The current status of leafy spurge on the Blackfoot River Watershed indicates there are a few infestations and the potential for spread throughout the basin. Managing to reduce dispersal using control tactics that at least minimize seed production should keep leafy spurge from infesting more of Bingham County and allow land managers to remove existing infestations. Focused management to roads and streams would make containment a possibility to prevent leafy spurge from reaching its potential within the county.

Conclusion.

The infestations of leafy spurge in Bingham County total 0.015% of the county. Our occurrence model suggests that 84% of the county could sustain leafy spurge. The occurrence model calculates a range of probabilities and those need to be hardened into classes according to susceptibility to invasion in order to be useful to land managers. We have created 6 classes with class 0 suggesting areas not susceptible and classes 1 to 5 potentially susceptible. Two strategies are available to survey crews, the first is to use the dispersal routes in conjunction with the occurrence model to reduce the area to survey. Secondly, high priority areas could be surveyed to a buffer distance of 500 meters.